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Quantifying the impact of a weed in a perennial ryegrass–white clover pasture

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Any plant not sown from seed is often labeled a weed in improved pastures of New Zealand. Most improved pastures are a mix of perennial ryegrass and white clover but generally are infested with broadleaf weeds. Changes in forage production due to individual weeds were determined using measurements of perennial ryegrass and white clover before and after dairy cattle, beef cattle, or sheep grazing under, near, and far from individual plants of six rosette-forming weed species throughout a growing season. The larger weeds, bull thistle and musk thistle, reduced the amount of forage utilized 42 and 72%, respectively, in beef cattle– and sheep-grazed hill-country pastures. Forage production under and near Canada thistle, hedge mustard, broadleaf plantain, and hairy buttercup in a dairy pasture was greater (136, 140, 178, and 450%, respectively) than in the control areas. Although the dairy pasture was grazed following recommended grazing procedures, our results indicate that this grazing system was not maximizing forage yield potentials of perennial ryegrass and white clover and that these weeds served as an indicator that the pasture was being overgrazed.

Nomenclature: Broadleaf plantain, *Plantago major* L. PLAMA; bull thistle, *Cirsium vulgare* (Savi) Tenore CIRVU; Canada thistle, *Cirsium arvense* (L.) Scop. CIRAR; hairy buttercup, *Ranunculus sardous* Crantz RANSA; hedge mustard, *Sisymbrium officinale* (L.) Scop. SSYOF; musk thistle, *Carduus nutans* L. CRUNU; perennial ryegrass, *Lolium perenne* L.; white clover, *Trifolium repens* L.

Key words: Interference, facilitation.

Many farmers with improved pastures of perennial ryegrass and white clover in New Zealand consider any other plant species in the field a weed. This is especially the case for broadleaf plants. However, little is actually known about the effects of many plant species on forage production of perennial ryegrass and white clover. Studies have been conducted that demonstrate detrimental effects on forage growth because of infestations of bull thistle (Hartley 1983; Kelly and Popay 1985), musk thistle (Thompson et al. 1987; Wardle et al. 1994), Canada thistle (Haggar et al. 1986), and tansy ragwort (*Senecio jacobaea*) (Wardle et al. 1995). Hartley (1983) determined that one bull thistle plant per square meter could reduce sheep live-weight gain in the summer over 20% because of reduced forage production. Thompson et al. (1987) calculated that musk thistle at a density of 0.1 plant m^{-2} would reduce forage productivity 8% during the season that it flowers. The loss of forage productivity, added to the fact that these plants are largely unpalatable, resulted in their being undesirable in pastures.

However, there are a large number of exotic plant species that volunteer in pastures in New Zealand. Many of these plants can occur in high densities, and some of them might not reduce forage production. Generally, the interaction among plant populations is termed interference, where one species' growth is altered by the presence of another (Radosevich et al. 1997). The presence of one species, however, might create an environment that favors the growth of another species, which is referred to as facilitation. An example of facilitation would be the inhibition of herbivory (cattle or sheep grazing) because of the presence of one plant species within a plant community, resulting in the favorable growth of another (Radosevich et al. 1997).

Six weed species were chosen for this study: musk thistle, Canada thistle, bull thistle, broadleaf plantain, hedge mustard, and hairy buttercup. Musk thistle is a biennial broadleaf plant, germinating in winter or spring and flowering in the second summer after more than a year in a rosette form. Bull thistle is an annual or biennial broadleaf plant, germinating in winter or spring and flowering in the first or second summer after a period in a rosette form. Canada thistle is a perennial broadleaf plant with a creeping root system, which gives rise to aerial shoots that elongate after a rosette period. Hedge mustard is a winter, annual broadleaf plant that initially forms a rosette before elongating into a rounded tangled mass of branches, which is easily rolled by the wind after senescence. Hairy buttercup is a winter annual broadleaf plant that forms a rosette before elongating up to 45 cm. Broadleaf plantain is a short-lived, perennial broadleaf plant that only has rosette leaves and a flower stalk that grows up to 30 cm (Roy et al. 1998).

The objective of this research was to determine the consequences to perennial ryegrass and white clover forage productivity because of the presence of individual plants of six rosette-forming broadleaf plant species: musk thistle, Canada thistle, bull thistle, broadleaf plantain, hedge mustard, and hairy buttercup. The measured effects included dry matter accumulation of perennial ryegrass, white clover, and weedy monocotyledons dicotyledons.

Materials and Methods

All pastures were predominately perennial ryegrass and white clover. The study site for the musk thistle experiment was located in a pasture outside of Whitehall, New Zealand, on the Oliver Farm (37°52′S, 175°37′E), rotationally grazed by sheep and beef cattle for 1 wk on a 1- to 2-mo basis (Table 1), with a stocking rate of 1.5 cows or 7 sheep ha^{-1}. The site is moderately sloping with a northeast aspect, has an elevation of 320 m, and the soil is a Tirau silty loam.

The study site for the bull thistle experiment was located east of the AgResearch Hill Station, Whatawhata, New Zealand (37°48′S, 175°05′E), on a pasture that was rotationally grazed by beef cattle for 1 wk on a 1- to 2-mo rotation (Table 1) at a stocking rate of 1.5 cows ha^{-1}. The site is moderately sloping with a northeast aspect, has an average elevation of 120 m, and the soil is a Dunmore silty loam.

The site for the Canada thistle, hedge mustard, hairy buttercup, and broadleaf plantain experiment was located in a dairy paddock near Hamilton, New Zealand, on the Fransen farm (37°46′S, 175°20′E) (Table 1). The site is flat with an elevation of 40 m, and the soil is a friable Te Rapa peaty loam. The grazing rotation in the dairy pasture was 1 d of grazing followed by 27 d of rest (Table 1), with a mean stocking rate of 2.4 cows ha^{-1}. Dairy pastures were typically grazed until approximately 1,500 kg ha^{-1} of plant biomass remained in the field (Stephens 2001), which is consistent with standard dairy pasture management (Smetham 1990). Postgrazing clipping to bare ground in control pastures confirmed that the grower left approximately 1,500 kg ha^{-1} of vegetation (Stephens 2001).

The study was conducted in the 1998–1999 and the 1999–2000 growing seasons. During the first growing season, harvests strictly followed the methods developed by Wardle et al. (1994), which involved clipping vegetation to 1 cm and measuring regrowth after 2 wk. The frequency and severity of the clipping did not simulate grazing, and a summer dry spell resulted in the senescence of many plant species, resulting in inadequate replication. Therefore during the second year of the study, methods were altered to more realistically measure the impact of the weed on both forage productivity, utilization of perennial ryegrass and white clover, and livestock behavior throughout the season. Only the 1999–2000 growing season data were analyzed and discussed in this article.

In early spring (October) of 1999, about 100 isolated plants of each species (600 plants) that were close to peak rosette, where the weed species had not commenced vertical growth, were identified and the rosette size was determined. The location was marked with a wooden stake (2.5 by 5 by 45 cm) that was placed at least 50 cm from the plant of interest to avoid labeling impact on the plant and pounded in until only 10 cm was above ground to reduce damage and loss from curious livestock. Vegetation was harvested just before grazing (pregraze) or immediately after grazing (postgraze), using a modification of the methodology described by Wardle et al. (1994). During a harvest, the diameter of each plant rosette was measured again because the rosette size was often different compared with the initial measurement (W-zone). A ring 10 cm wide was marked off from the edge of the W-zone (R-zone), and a 25- by 25-cm quadrat (control) was placed in an area that was more than 1 m from the harvested weed plant and did not contain the investigated weed species (Figure 1). The vegetation in W- and R-zones and in control was then cut back to 2 cm and the harvested material bagged separately. The weed

TABLE 1. Pastures, plant species, and harvest dates for study.[a]

		Date							
		Rosette		Flowering		Senescence		Post senescence	
Pasture	Plant	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Oliver	Musk thistle	October 6, 1999	October 11, 1999	December 16, 1999	December 23, 1999	March 15, 2000	March 23, 2000	May 22, 2000	June 23, 2000
Whatawhata	Bull thistle	October 4, 1999	October 8, 1999	December 22, 1999	January 5, 2000	February 18, 2000	February 24, 2000	April 3, 2000	April 10, 2000
Fransen	Hedge mustard	October 19, 1999	October 21, 1999	November 16, 1999	November 19, 1999	January 11, 2000	January 14, 2000	March 17, 2000	March 20, 2000
				December 14, 1999	December 16, 1999				
Fransen	Canada thistle	October 19, 1999	October 21, 1999	December 14, 1999	December 16, 1999	February 17, 2000	February 21, 2000	April 14, 2000	April 17, 2000
		November 16, 1999	November 19, 1999	January 11, 2000	January 14, 2000				
Fransen	Hairy buttercup	November 16, 1999	November 19, 1999	December 14, 1999	December 16, 1999	February 17, 2000	February 21, 2000	April 14, 2000	April 17, 2000
				January 11, 2000	January 14, 2000				
Fransen	Broadleaf plantain	December 14, 1999	December 16, 1999	January 11, 2000	January 14, 2000	February 17, 2000	February 21, 2000	April 14, 2000	April 17, 2000

[a] Abbreviations: Pre, 1 or 2 d before grazing; Post, 1 or 2 d after grazing.

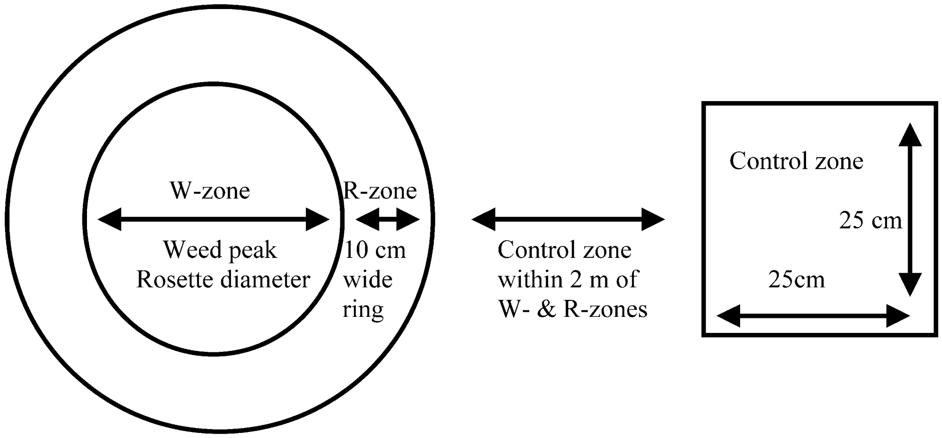

FIGURE 1. The pasture biomass assessment experimental zone design.

plant of interest in the W-zone was clipped at ground level and bagged separately; because of this destructive harvest, a new weed plant was used for each harvest. Harvests continued until 2 mo after senescence for each weed species (Table 1). The collected plant material was kept cool (4 C) until species compositions could be determined (ryegrass, clover, weedy monocotyledons, and dicotyledons). With large samples, a randomized subsample with a minimum of 400 pieces of vegetation was used. Fresh weights and dry weights (after drying for at least 24 h at 80 C) were determined. All data were transformed to a gram dry weight per square meter basis.

For each weed species, eight plants and their associated W-, R-, and control zones were harvested 1 or 2 d before grazing. One to two days after grazing, four weed plants and their associated W-, R-, and control zones were harvested. The pregraze harvest represented forage accumulation that occurred since the last grazing and was used to determine the impact of the weed on biomass accumulation in the zones. The postgraze harvest represented the forage biomass not grazed in the zones and illustrated the impact of the weed on livestock grazing behavior.

Harvests were completed through three life stages of each weed species, broadly adopted from Wardle et al. (1994): peak rosette, where the weed species had not commenced vertical growth but reached maximum rosette size; full flowering, where the vertical growth had ceased and flowering was well under way; and senescence, where the weed had died, or in the case of the perennial broadleaf plantain, dieback of vegetative growth had occurred and seed-shed was well under way. Because of the grazing frequency in the dairy pasture and the development time of the weeds, sometimes there were more than three pairs of harvests for each weed species (Table 1).

Mean temperatures in the region range from 17 to 20 C in summer and 8 to 10 C in winter. Summer high temperatures can reach 30 C, and winter lows can fall to -4 C. Rainfall in the area averages 120 cm yr^{-1} with most falling in autumn and winter. Two to three weeks of dry periods are common in summer. The study was conducted on three pastures throughout the 1999–2000 growing season in weather that was typical for the region, with close to average temperatures and precipitation.

Analysis

For each plant species, data were analyzed using the SAS analysis of variance procedure[1] for changes in available biomass from spring to autumn and differences in available and remaining biomass in the three harvest zones. Because of the variability associated with pasture research, data were sometimes log transformed to meet assumptions of normality. All figures are presented with nontransformed data. Means separation was determined using Tukey's honestly significant difference.

We were not able to compare statistically the amount of vegetation eaten in each zone because of the use of a different weed plant at each harvest. Vegetation utilization, however, was determined using comparisons of vegetation before and after grazing. At each date and for each plant species in the W-zone, the total vegetation biomass utilized was estimated (biomass of vegetation postgraze was subtracted from vegetation biomass pregraze). Vegetation biomass utilization was estimated from the equation:

Total biomass utilized = W-zone biomass utilized/control biomass utilized.

Results and Discussion

Musk thistle (Figure 2) had no impact on pregraze forage biomass accumulation in the W-zone except at full flowering, where there was twice as much forage biomass as that in the R-zone and control. Bull thistle (Figure 3) did not affect total pregraze forage biomass accumulations in the W-zone at any harvest compared with the control. The presence of both bull thistle and musk thistle had an impact on postgraze forage biomass. At the peak rosette stage, there was more forage biomass in the W-zone compared with the R-zone and control (Figures 2 and 3). Musk thistle had more forage biomass in the W-zone compared with the R-zone and control (Figure 2) at full flowering, whereas bull thistle at full flowering had more forage biomass in both the W- and R-zones than in the control (Figure 3). The sheep and cattle in these pastures were unwilling to graze vegetation that was growing up through either bull thistle or musk thistle, resulting in considerable unutilized forage biomass. At full flowering, the long leaf-tip thorns of bull thistle discouraged cattle from eating vegetation in the R-zone as well,

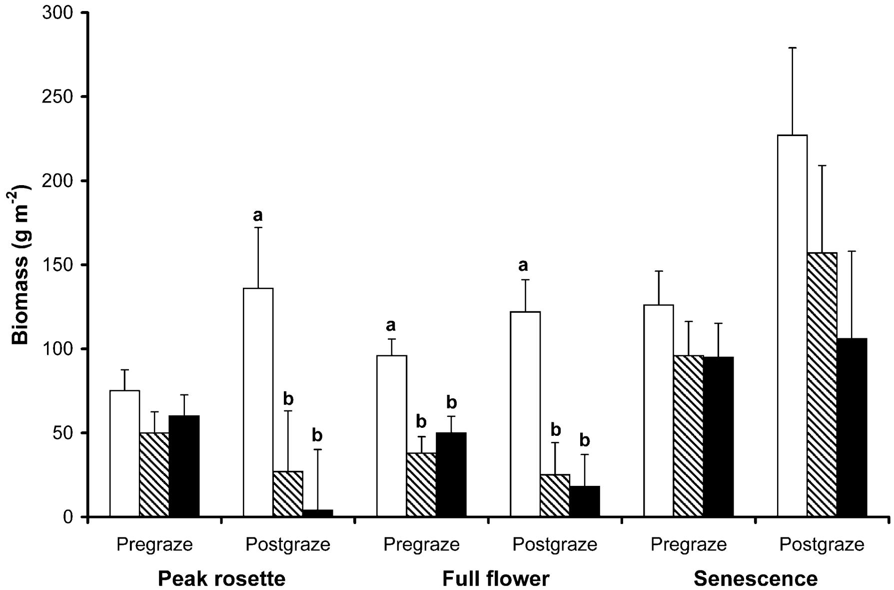

FIGURE 2. Impact of musk thistle on pregrazing and postgrazing total forage biomass, excluding the weed of interest in the area occupied, or previously occupied by the weed rosette (W-zone; white bar), a 10-cm ring around the weed rosette (R-zone; hashed bar), and a 25- by 25-cm pasture control (black bar). Bars with the same letters at a harvest time do not differ at the 5% level. Vertical bars represent the standard error.

which resulted in an accumulation of unutilized forage biomass.

Forage productivity in the hill country was about half that in the dairy pasture, which is typical in New Zealand, because of naturally less fertile soils in the hill country and the supplemental fertilization that occurs in dairy pastures. In the dairy pasture, hedge mustard, Canada thistle, and hairy buttercup often had more forage biomass in the W-zone compared with the R-zone and control, both before and after grazing (Figures 4–6). Broadleaf plantain only had more forage biomass in the W-zone at the senescence harvest (Figure 7). Dairy cattle will eat hedge mustard when it is in the rosette stage, but on bolting, they avoid it. This is evident in Figure 4, where there were no differences in forage biomass in the W-zone at the first harvest followed by increased amounts of forage biomass in the W-zone in the second and fourth pregraze samples. Cattle will avoid Canada thistle and hairy buttercup at all stages of growth, resulting in increased forage biomass in the W-zone (Figures 5 and 6) compared with the R-zone and control. The increased forage biomass remaining in the W-zone of Canada thistle and hairy buttercup postgrazing resulted in more forage biomass in the W-zone just before the next grazing. Cattle will eat broadleaf plantain even though its small size and very prostrate growth habit protect it somewhat from grazing (Figure 7). After senescence of the aboveground portion of broadleaf plantain, there was a large increase in pasture biomass in the W-zone (Figure 7). The cause for this

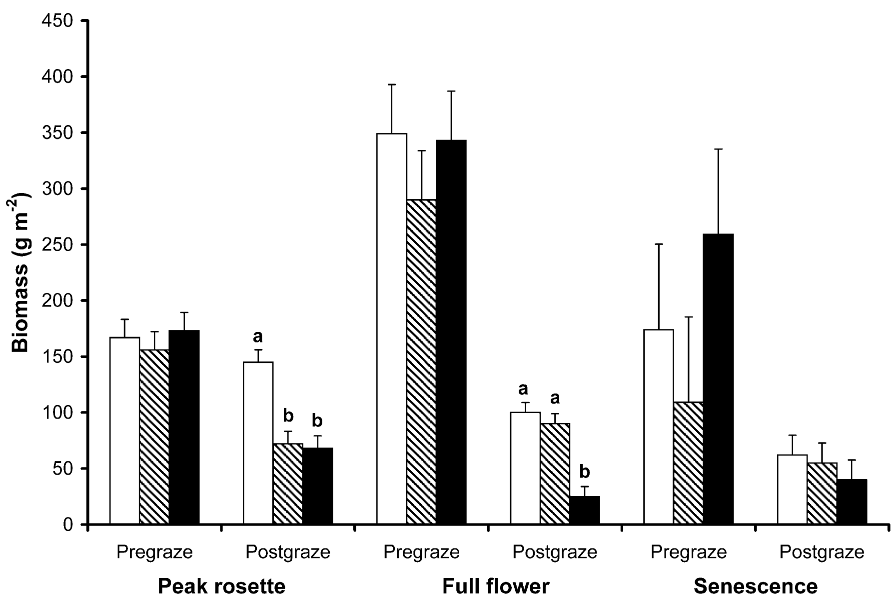

FIGURE 3. Impact of bull thistle on pregrazing and postgrazing total forage biomass, excluding the weed of interest in the area occupied, or previously occupied by the weed rosette (W-zone; white bar), a 10-cm ring around the weed rosette (R-zone; hashed bar), and a 25- by 25-cm pasture control (black bar). Bars with the same letters at a harvest time do not differ at the 5% level. Vertical bars represent the standard error.

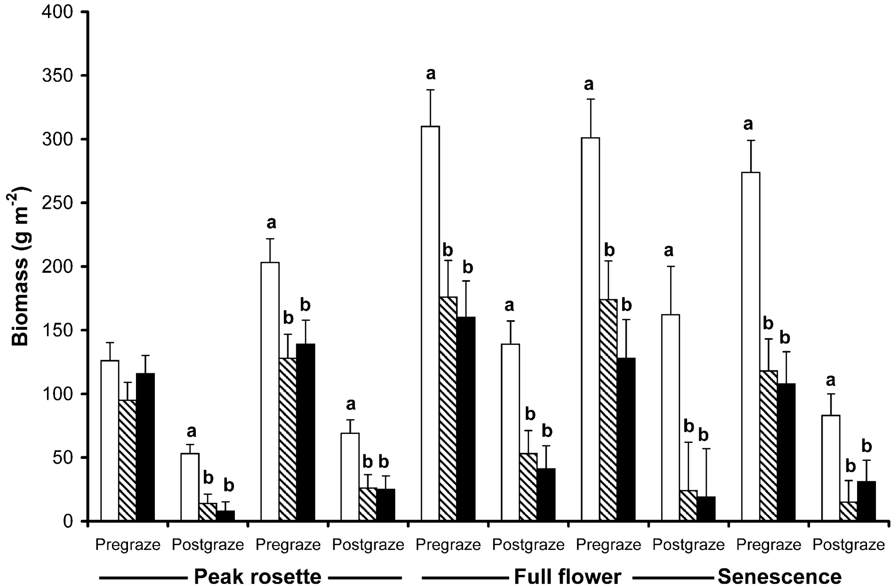

FIGURE 4. Impact of hedge mustard on pregrazing and postgrazing total forage biomass, excluding the weed of interest in the area occupied, or previously occupied by the weed rosette (W-zone; white bar), a 10-cm ring around the weed rosette (R-zone; hashed bar), and a 25- by 25-cm pasture control (black bar). Bars with the same letters at a harvest time do not differ at the 5% level. Vertical bars represent the standard error.

increase could be attributed to release of nutrients from decaying leaves, to an increase in soil moisture or nutrients available to surrounding plants, or to the impact of increased nitrogen fixation by white clover roots in the W-zone (Stephens 2001). In the dairy pasture, forage biomass production varied with the season as is normal for the region (Figures 4–7), with forage biomass production increasing in the spring and early summer and falling off in late summer as a result of reduced rainfall.

Because all sampling was destructive and each sampling involved different plants, we were not able to compare statistically the amount of vegetation eaten, though it was possible with the data set to estimate forage productivity and utilization (Figure 8). The amount of forage biomass under the weed before grazing was similar to that of areas without weeds for bull and musk thistle in the hill-country pastures. However in the dairy pasture, there was more forage biomass under the weed than in the pasture, especially for hairy buttercup with up to 300% more forage. After grazing, forage biomass under all the weeds, except for broadleaf plantain, was much greater than in the control areas, indicating that animals were avoiding the forage under these plants (Figure 4). The difference was not as large for hedge mustard postgrazing because it was partially grazed while a rosette. The leaf shape of hedge mustard allows light and plant leaves to penetrate through the rosette. In addition, while a rosette, hedge mustard leaves will change from a prostrate habit to a more erect habit as pasture height increases, especially in

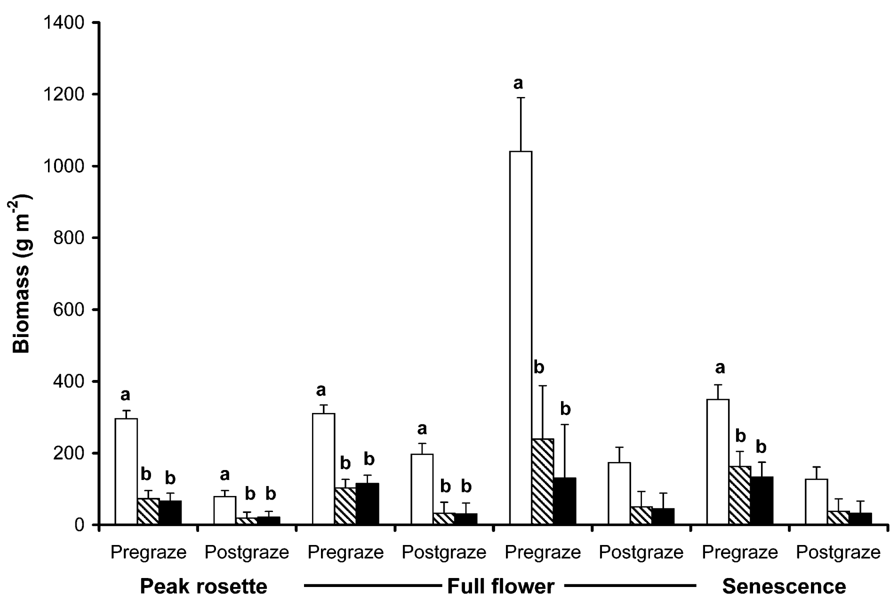

FIGURE 5. Impact of Canada thistle on pregrazing and postgrazing total forage biomass, excluding the weed of interest in the area occupied, or previously occupied by the weed rosette (W-zone; white bar), a 10-cm ring around the weed rosette (R-zone; hashed bar), and a 25- by 25-cm pasture control (black bar). Bars with the same letters at a harvest time do not differ at the 5% level. Vertical bars represent the standard error.

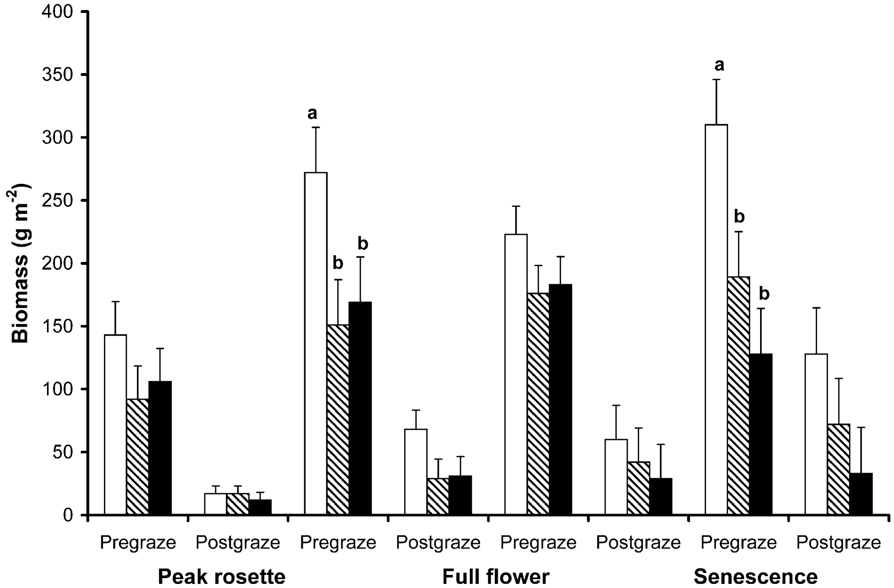

FIGURE 6. Impact of hairy buttercup on pregrazing and postgrazing total forage biomass, excluding the weed of interest in the area occupied, or previously occupied by the weed rosette (W-zone; white bar), a 10-cm ring around the weed rosette (R-zone; hashed bar), and a 25- by 25-cm pasture control (black bar). Bars with the same letters at a harvest time do not differ at the 5% level. Vertical bars represent the standard error.

a dense sward. These factors keep it from competing as strongly for light as do most other weeds with a prostrate growth habit and make it more susceptible to grazing.

An important question is how much forage was actually utilized (grazed by livestock) in the W-zone. With the normalized data, it is evident that musk thistle and bull thistle reduced the amount of utilized forage (72 and 42%, respectively) for cattle (Figure 8) during the growing season. Postgrazing there were two and three times as much vegetation under the rosettes of these large thistles than in the control plots, but most of this vegetation was lost to senescence and therefore, was not utilized. In the dairy pasture, the amount of utilized forage in the W-zone of Canada thistle and hedge mustard was slightly greater than in the control areas (136 and 140%, respectively), whereas under hairy buttercup and broadleaf plantain the increase in utilized forage was sizable (450 and 178%, respectively).

Certainly one would not expect to measure an increase in perennial ryegrass and white clover consumption from an area under an uneaten weed, but there are several plausible explanations for this finding related to increased forage production. Because the vegetation under the weed was not grazed as much as the rest of the pasture, recovery of the vegetation would be much quicker because of more available photosynthetic material (Jarman and Sinclair 1979). In addition, these larger plants would be able to exploit soil resources more rapidly than the more heavily grazed neighboring plants, resulting in an enhanced growth potential and

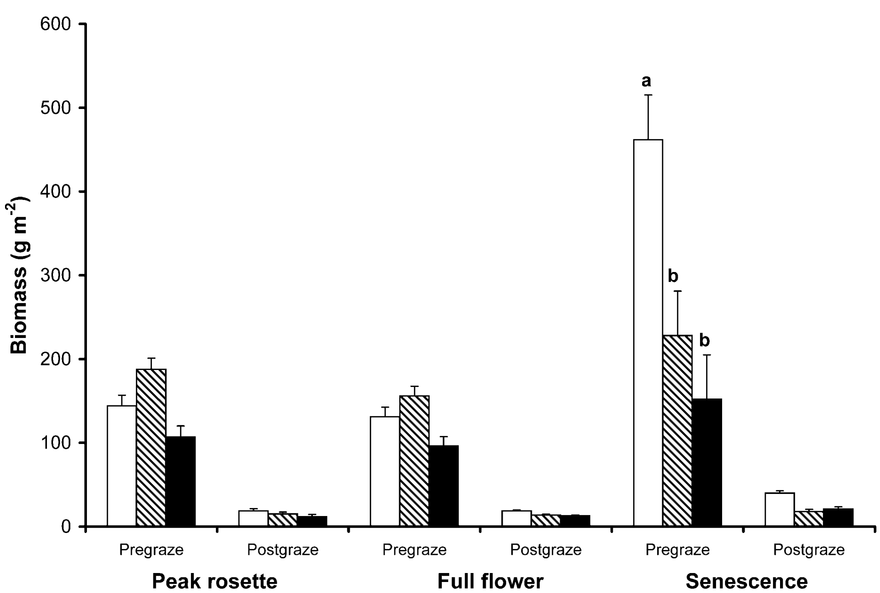

FIGURE 7. Impact of broadleaf plantain on pregrazing and postgrazing total forage biomass, excluding the weed of interest in the area occupied, or previously occupied by the weed rosette (W-zone; white bar), a 10-cm ring around the weed rosette (R-zone; hashed bar), and a 25- by 25-cm pasture control (black bar). Bars with the same letters at a harvest time do not differ at the 5% level. Vertical bars represent the standard error.

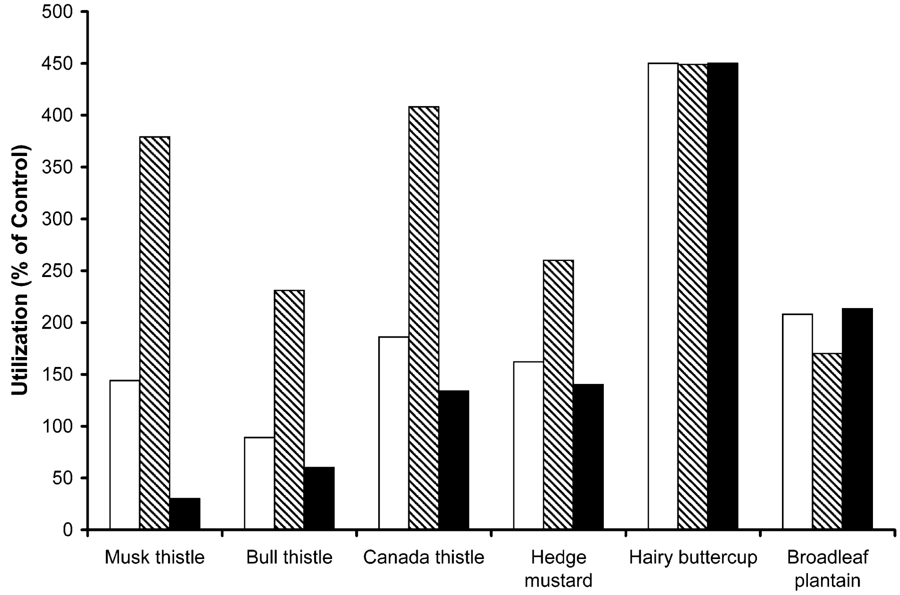

FIGURE 8. Normalized season-long forage productivity pregrazing (white bar), postgrazing (hashed bar), and forage utilization (black bar) in the area occupied, or previously occupied, by the weed rosette (W-zone) expressed as a percentage of the control area.

increased competitiveness from these more lightly grazed plants against the more heavily grazed neighboring plants (Clement et al. 1978; Smetham 1990). The root systems of hedge mustard, hairy buttercup, and Canada thistle extract resources from deeper in the soil than do perennial ryegrass or white clover and therefore, they would not be entirely competing directly for the same soil resources (Tilman et al. 2001). Competition for light during the rosette form from hairy buttercup, broadleaf plantain, Canada thistle, and, to a lesser extent, hedge mustard would reduce plant growth of competing perennial ryegrass and white clover plants growing in the W-zone at the rosette stage. After bolting, only broadleaf plantain would continue to exert this shading pressure because the rosette leaves of broadleaf plantain do not rise up with the bolting reproductive stem. However, the growth reduction due to shading appears to be minimal compared with the advantage gained by protection from grazing. In addition, broadleaf plantain enhances nitrogen fixation by white clover in the W-zone (Stephens 2001), which would result in enhanced growth of surrounding plants.

An argument could be made that the weeds in the dairy pasture can serve as indicators that grazing pressure was too great, such that the plants in the R-zone and control were not able to recover as quickly as the more lightly grazed plants in the W-zone despite the presence of the weed. Although the owner was closely following recommended grazing procedures for a dairy farm with a 28-d rotation and grazing down to 1,500 kg ha^{-1} of plant biomass in the field, results of this research indicate that this system was not maximizing forage yield potentials of perennial ryegrass and white clover on that pasture.

Essentially, species composition did not change in the W-zone, R-zone, and control during the course of this experiment (Stephens 2001). In addition, most vegetation components (perennial ryegrass, white clover, and weedy monocotyledons dicotyledons) in the W- and R-zones increased and decreased in parallel with the total forage biomass. There were two exceptions. First, at the senescence harvest, the W-zone of bull thistle and musk thistle exhibited an increase in the proportion of dicotyledonous-weed biomass and a corresponding decrease in the perennial ryegrass proportion. This agrees with Wardle et al. (1994) in studies with bull thistle. However, it does not agree with Wardle et al. (1993a, 1993b), who suggested musk thistle moves the perennial ryegrass and white clover competitive balance in favor of the grass. Second, at the senescence harvest, the W-zone of Canada thistle and hairy buttercup exhibited a decreased proportion of dicotyledonous plants (not including white clover) and a corresponding increase in the proportion of perennial ryegrass (Stephens 2001). Canada thistle and hairy buttercup appear to provide a suitable environment for the seasonal return of perennial ryegrass after the summer dormancy of that pasture species.

A bull thistle or a musk thistle plant inhibited grazing; therefore, although present from establishment in the previous autumn to senescence the subsequent summer, the portion of the ground influenced by the plant is agriculturally not producing usable forage to its potential, despite the amount of forage biomass present. This confirms established views that these weeds are detrimental to agricultural production (Kelly and Popay 1985; Popay and Medd 1990). When the weed bolts lifting the rosette, grazing in the W- and R-zones increases marginally, but considerable inhibition of grazing is still seen until plant senescence.

The presence of a Canada thistle plant had little effect on forage biomass production and utilization. Grazing inhibition was reduced at peak rosette. However, as the weed bolted, the increased forage biomass in the W-zone was utilized, offsetting the earlier reduction in utilized forage. The early harvest did support the view that Canada thistle inhibits grazing (Haggar et al. 1986); however, subsequent harvests did not, and the impact of a solitary Canada thistle on total forage biomass productivity and utilization was minimal.

The presence of hedge mustard, broadleaf plantain, or hairy buttercup plant increased forage biomass productivity and utilization in the W-zone. The forage productivity in the W-zone was increased during the period when the weed was unpalatable and therefore unattractive to livestock. As a result, grazing was less severe, reducing the length of the lag phase for plant growth after grazing. Dairy cattle utilized much of the increased biomass.

This research was conducted to determine the impact of an individual weed on forage biomass productivity and utilization and did not address the issue of patches or dense infestations of weeds. The studied weeds can be divided into three separate groups: those that reduce, have no effect, or increase forage biomass and utilization in the W-zone. The two hill-country large thistle species reduced forage utilization. Canada thistle had no effect on forage utilization, whereas the lowland alluvial plain weeds—hedge mustard, broadleaf plantain, and hairy buttercup—increased forage biomass productivity and utilization. Producers need to evaluate which species are present in a pasture to determine potential reductions in forage production as a part of their weed control decision-making process. In addition, producers can use the perennial ryegrass and white clover growth around particular weeds, such as hedge mustard, as an indicator of the grazing pressure their animals are applying to a pasture.

Sources of Materials

[1] SAS version 6.04, SAS Institute Inc., Campus Drive, Cary, NC 27513.

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